

CLAIMS

What is claimed is:

1. A plasma generating apparatus comprising:
a chamber;
a first set of electrodes comprising three electrodes, wherein each electrode of the first set of electrodes is configured to be coupled to a single phase of a three phase alternating current (AC) power supply, the three electrodes of the first set of electrodes being disposed about a longitudinal axis of the chamber; and
at least another set of electrodes comprising three electrodes, wherein each electrode of the at least another set of electrodes is configured to be coupled to a single phase of another three phase alternating current (AC) supply, the three electrodes of the at least another set of electrodes being disposed about the longitudinal axis of the chamber, and wherein the at least another set of electrodes is displaced along the longitudinal axis relative to the first set of electrodes.
2. The apparatus of claim 1, wherein the chamber includes an inlet at a first end and an outlet at a second opposing end thereof.
3. The apparatus of claim 2, wherein the inlet is located and configured to introduce a material into the chamber at a location which is substantially along a centerline of an arc produced by the first set of electrodes and the at least another set of electrodes.
4. The apparatus of claim 3, wherein the outlet is configured as a converging nozzle.
5. The apparatus of claim 1, wherein each electrode of the first set of electrodes is configured to be displaced relative to the longitudinal axis.
6. The apparatus of claim 5, wherein each electrode of the at least another set of electrodes is configured to be displaced relative to the longitudinal axis.

7. The apparatus of claim 6, further comprising a plurality of actuators, wherein each electrode of the first set of electrodes and each electrode of the at least another set of electrodes is coupled with an actuator of the plurality of actuators and displaceable thereby.

8. The apparatus of claim 7, further comprising a plurality of sliding assemblies associated with the plurality of actuators, wherein each sliding assembly comprises a first frame member substantially rigidly coupled with the chamber, at least one linear rod bearing coupled between the frame member and its associated actuator, and a sliding member coupled with an associated electrode and configured to be displaced substantially linearly along the at least one linear rod bearing.

9. The apparatus of claim 7, wherein the chamber further comprises a body having an internal surface, an external surface and at least one passage defined between the internal surface and the external surface.

10. The apparatus of claim 9, further comprising at least one cooling port in fluid communication with the at least one passage.

11. The apparatus of claim 10, wherein the body defines at least one opening from the external surface through the internal surface and wherein a viewing port is coupled with the at least one opening.

12. The apparatus of claim 6, wherein each electrode of the first set of electrodes extends at an acute angle relative to the longitudinal axis.

13. The apparatus of claim 12, wherein each electrode of the at least another set of electrodes extends at a substantially normal angle relative to the longitudinal axis.

14. The apparatus of claim 13, wherein each electrode of the first set of electrodes is disposed circumferentially about the longitudinal axis at an angle of approximately 120° relative to adjacent electrodes of the first set of electrodes.

15. The apparatus of claim 14, wherein each electrode of the at least another set of electrodes is disposed circumferentially about the longitudinal axis at an angle of approximately 120° relative to adjacent electrodes of the at least another set of electrodes.

16. The apparatus of claim 15, wherein the first set of electrodes exhibits a first circumferential orientation about the longitudinal axis and the at least another set of electrodes exhibits a second circumferential orientation about the longitudinal axis different than the first circumferential orientation.

17. The apparatus of claim 16, wherein the second circumferential orientation includes the electrodes of the at least another set of electrodes being rotated approximately 60° about the longitudinal axis relative to the electrodes of the first set of electrodes.

18. The apparatus of claim 1, wherein the at least another set of electrodes includes a second set of electrodes and a third set of electrodes displaced along the longitudinal axis relative to the second set of electrodes.

19. The apparatus of claim 1, wherein the electrodes are formed of a material comprising graphite.

20. The apparatus of claim 1, wherein the electrodes each include at least one metallic tubular member.

21. The apparatus of claim 20, wherein the at least one metallic tubular member includes a first metallic tubular member and a second metallic tubular member, wherein the second metallic tubular member is disposed within the first metallic tubular member and wherein the first and second tubular members are sized, located and configured to define an annular gap therebetween.

22. The apparatus of claim 21, further comprising an inlet in fluid communication with an interior portion of the second tubular member and an outlet in fluid communication with the annular gap.

23. The apparatus of claim 20, wherein each electrode further includes an electrode tip removably coupled with the at least one metallic tubular member.

24. An arc generating apparatus comprising:
a first set of electrodes comprising three electrodes, wherein each electrode of the first set of electrodes is configured to be coupled to a single phase of a three phase alternating current (AC) power supply, the three electrodes of the first set of electrodes being disposed about a defined axis; and
at least a another set of electrodes comprising three electrodes, wherein each electrode of the at least another set of electrodes is configured to be coupled to a single phase of another three phase alternating current (AC) supply, the three electrodes of the at least another set of electrodes being disposed about the longitudinal axis of the chamber, and wherein the at least another set of electrodes is displaced from to the first set of electrodes along the defined axis.

25. The apparatus of claim 24, wherein each electrode of the first set of electrodes is configured to be displaced relative to the defined axis.

26. The apparatus of claim 25, wherein each electrode of the at least another set of electrodes is configured to be displaced relative to the defined axis.

27. The apparatus of claim 26, wherein each electrode of the first set of electrodes extends at an acute angle relative to the defined axis.

28. The apparatus of claim 27, wherein each electrode of the at least another set of electrodes extends at a substantially normal angle relative to the defined axis.

29. The apparatus of claim 28, wherein each electrode of the first set of electrodes is disposed circumferentially about the defined axis at an angle of approximately 120° relative to adjacent electrodes of the first set of electrodes.

30. The apparatus of claim 29, wherein each electrode of the at least another set of electrodes is disposed circumferentially about the defined axis at an angle of approximately 120° relative to adjacent electrodes of the at least another set of electrodes.

31. The apparatus of claim 30, wherein the first set of electrodes exhibits a first circumferential orientation about the defined axis and the at least another set of electrodes exhibits a second circumferential orientation about the defined axis different than the first circumferential orientation.

32. The apparatus of claim 31, wherein the second circumferential orientation includes the electrodes of the at least another set of electrodes being rotated approximately 60° about the defined axis relative to the electrodes of the first set of electrodes.

33. The apparatus of claim 32, wherein the at least another set of electrodes includes a second set of electrodes and a third set of electrodes displaced along the defined axis relative to the second set of electrodes.

34. The apparatus of claim 24, wherein the electrodes are formed of a material comprising graphite.

35. The apparatus of claim 24, wherein the electrodes each include at least one metallic tubular member.

36. The apparatus of claim 35, wherein the at least one metallic tubular member includes a first metallic tubular member and a second metallic tubular member, wherein the second metallic tubular member is disposed within the first metallic tubular member and wherein

the first and second tubular members are sized, located and configured to define an annular gap therebetween.

37. The apparatus of claim 36, further comprising an inlet in fluid communication with an interior portion of the second tubular member and an outlet in fluid communication with the annular gap.

38. The apparatus of claim 35, wherein each electrode further includes an electrode tip removably coupled with the at least one metallic tubular member.

39. A plasma arc reactor comprising:
a first chamber section;
at least another chamber section wherein the first chamber section and the at least another chamber section are configured and located to at least partially define a chamber body;
a first set of electrodes comprising three electrodes disposed at least partially within the first chamber section, wherein each electrode of the first set of electrodes is configured to be coupled to a single phase of a three phase alternating current (AC) power supply, the three electrodes of the first set of electrodes being disposed about a longitudinal axis of the chamber body; and
at least another set of electrodes comprising three electrodes disposed at least partially within the at least another chamber section, wherein each electrode of the at least another set of electrodes is configured to be coupled to a single phase of another three phase alternating current (AC) supply, the three electrodes of the at least another set of electrodes being disposed about the longitudinal axis of the chamber body, and wherein the at least another set of electrodes is displaced along the longitudinal axis relative to the first set of electrodes.

40. The reactor of claim 39, wherein each electrode of the first set of electrodes is configured to be displaced relative to the longitudinal axis.

41. The reactor of claim 40, wherein each electrode of the at least another set of electrodes is configured to be displaced relative to the longitudinal axis.
42. The reactor of claim 41, further comprising a plurality of actuators, wherein each electrode of the first set of electrodes and each electrode of the at least another set of electrodes is coupled with an actuator of the plurality of actuators and displaceable thereby.
43. The reactor of claim 42, wherein the first chamber section further comprises an internal surface, an external surface and at least one passage defined therebetween.
44. The reactor of claim 43, further comprising at least one cooling port in fluid communication with the at least one passage of the first chamber section.
45. The reactor of claim 44, wherein the at least another chamber section further comprises an internal surface, an external surface and at least one passage defined therebetween.
46. The reactor of claim 45, further comprising at least one cooling port in fluid communication with the at least one passage of the at least another chamber section.
47. The reactor of claim 42, wherein each electrode of the first set of electrodes extends at an acute angle relative to the longitudinal axis.
48. The reactor of claim 47, wherein each electrode of the at least another set of electrodes extends at a substantially normal angle relative to the longitudinal axis.
49. The reactor of claim 48, wherein the first set of electrodes exhibits a first circumferential orientation about the longitudinal axis and the at least another set of electrodes exhibits a second circumferential orientation about the longitudinal axis different than the first circumferential orientation.

50. The reactor of claim 39, wherein the at least another chamber section is removably coupled with the first chamber section.

51. The reactor of claim 39, wherein the at least another chamber section includes a second chamber section removably coupled to the first chamber section and a third chamber section removably coupled to the second chamber section, and wherein the at least another set of electrodes includes a second set of electrodes disposed at least partially within the second chamber section and a third set of electrodes disposed at least partially within the third chamber section.

52. The reactor of claim 32, further comprising a spacer disposed between and removably coupled to each of the first chamber section and the at least another chamber section.

53. A system for processing materials comprising:
a chamber having an inlet at a first end thereof and an outlet at a second end thereof;
a first set of electrodes comprising three electrodes, the three electrodes of the first set of electrodes being disposed about a longitudinal axis of the chamber;
at least another set of electrodes comprising three electrodes, the three electrodes of the at least another set of electrodes being disposed about the longitudinal axis of the chamber, and wherein the at least another set of electrodes is displaced along the longitudinal axis relative to the first set of electrodes;
a first power supply including three-phase alternating current (AC) electrical service wherein each phase of the first power supply is coupled to an individual electrode of the first set of electrodes;
at least another power supply including three-phase AC electrical service wherein each phase of the at least another power supply is coupled to an individual electrode of the at least another set of electrodes.

54. The system of claim 53, further comprising a cooling system located and configured to transfer thermal energy away from the chamber.

55. The system of claim 54, wherein the cooling system further comprises a heat exchanger and at least one cooling line located and configured to accommodate circulation of a cooling fluid between the chamber and the heat exchanger.

56. The system of claim 55, wherein the cooling system further comprises a pump located and configured to circulate a cooling fluid through the at least one cooling line.

57. The system of claim 53, wherein the first power supply includes a first silicon controlled rectifier (SCR).

58. The system of claim 57, wherein the first SCR is configured to control a firing of each electrode of the first set of electrodes according to a phase angle of each phase of the first power supply.

59. The system of claim 53, wherein the at least another power supply includes at least another silicon controlled rectifier.

60. The system of claim 59, wherein the at least another SCR is configured to control a firing of each electrode of the at least another set of electrodes according to a phase angle of each phase of the at least another power supply.

61. The system of claim 60, wherein each electrode of the first set of electrodes is configured to be displaced relative to the longitudinal axis.

62. The system of claim 61, wherein each electrode of the at least another set of electrodes is configured to be displaced relative to the longitudinal axis.

63. The system of claim 62, further comprising a plurality of actuators, wherein each electrode of the first set of electrodes and each electrode of the at least another set of electrodes is coupled with an actuator of the plurality of actuators and displaceable thereby.

64. The system of claim 63, further comprising a first measurement device located and configured to determine at least one of a current and a voltage of each phase of the first power supply and produce a first signal responsive thereto, and at least one other measurement device located and configured to determine at least one of a current and a voltage of each phase of the at least another power supply and produce at least another signal responsive thereto.

65. The system of claim 64, wherein the plurality of actuators are each configured to displace their associated electrodes responsive to at least one of the first signal and the at least another signal.

66. The system of claim 65, wherein the inlet is located and configured to introduce a material into the chamber at a location which is substantially along a centerline of an arc produced by the first set of electrodes and the at least another set of electrodes.

67. The system of claim 66, wherein the outlet is configured as a converging nozzle.

68. The system of claim 67, further comprising a separation device coupled to the outlet of the chamber.

69. The system of claim 68 wherein the separation device includes at least one of a cyclone and a filter.

70. The system of claim 65, wherein each electrode of the first set of electrodes extends at an acute angle relative to the longitudinal axis.

71. The system of claim 70, wherein each electrode of the at least another set of electrodes extends at a substantially normal angle relative to the longitudinal axis.

72. The system of claim 71, wherein the first set of electrodes exhibits a first circumferential orientation about the longitudinal axis and the at least another set of electrodes

exhibits a second circumferential orientation about the longitudinal axis different than the first circumferential orientation.

73. A method of generating a plasma, the method comprising:
introducing a gas into a chamber;
providing a first set of electrodes comprising three electrodes disposed about a longitudinal axis of the chamber;
providing at least another set of electrodes comprising three electrodes disposed about the longitudinal axis and displaced along the longitudinal axis relative to the first set of electrodes;
coupling the first set of electrodes to a first power supply including coupling each electrode of the first set of electrodes to a phase of a three-phase alternating current (AC) power supply;
coupling the at least another set of electrodes to at least another power supply including coupling each electrode of the at least another set of electrodes to a phase of at least another three-phase power supply;
creating an arc among the first set of electrodes and the at least another set of electrodes within the chamber in the presence of the gas.

74. The method according to claim 73, further comprising determining at least one operational characteristic of the first power supply and at least one operational characteristic of the at least another power supply.

75. The method according to claim 74, wherein the determining at least one operational characteristic of the first power supply includes determining at least one of a current and a voltage of the first power supply, and wherein the determining at least one operational characteristic of the at least another power supply includes determining at least one of a current and a voltage of the at least another power supply.

76. The method according to claim 75, further comprising displacing at least one electrode of the first set of electrodes responsive to the determined at least one operational characteristic of the first power supply.

77. The method according to claim 76, further comprising displacing at least one electrode of the at least another set of electrodes responsive to the determined at least one operational characteristic of the at least another power supply.

78. The method according to claim 77, further comprising transferring thermal energy away from the chamber.

79. The method according to claim 77, further comprising controlling a phase angle of each phase of the first power supply.

80. The method according to claim 78, further comprising controlling a phase angle of each phase of the at least another power supply.

81. A method of generating a plasma, the method comprising:
introducing a gas into a chamber;
disposing at least a first plurality of electrodes at least partially within the chamber in a first arrangement such that a tip of at least one electrode is disposed a first distance from a tip of an adjacent electrode;
creating an arc among the at least a first plurality of electrodes in the chamber in the presence of a gas; and
displacing the at least one electrode such that the tip of the at least one electrode is disposed at a second distance from the tip of the adjacent electrode while maintaining the arc.

82. The method according to claim 81, wherein the disposing at least a first plurality of electrodes at least partially within the chamber further includes substantially symmetrically arranging the at least a first plurality of electrodes circumferentially about a longitudinal axis of the chamber.

83. The method according to claim 82, wherein displacing the at least one electrode further includes displacing each electrode of the plurality of electrodes.

84. The method according to claim 83, wherein the creating an arc among the at least a first plurality of electrodes further includes providing electrical service to each electrode, the method further comprising determining at least one operational parameter associated with the electrical service provided to each electrode wherein the displacing each electrode is responsive to the determined at least one operational parameter.

85. The method according to claim 81, wherein the disposing at least a first plurality of electrodes at least partially within the chamber further includes disposing a first set of electrodes at a first location along the longitudinal axis and disposing at least a second set of electrodes at a second location along the longitudinal axis displaced from the first location.